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Modeling Input Parameters for the Grand View PA Model v1.1

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TABLES

ACRONYMS AND ABBREVIATIONS

SB	safety basis
CR	concentration ratio
CSM	conceptual site model
DSC	discrete distribution
DU	depleted uranium
EFH	(EPA's) Exposure Factors Handbook
E/P ratio	escape/production ratio
EPA	(United States) Environmental Protection Agency
ET	evapotranspiration or evapotranspiritive
G	gamma distribution
GM	geometric mean
GSD	geometric standard deviation
HDPE	high-density polyethylene
LANL	Los Alamos National Laboratory
LN	log-normal distribution
N	normal distribution
PA	performance assessment
PRNCW	pasture and rangeland not cropland or woodland
RCRA	Resource Conservation and Recovery Act
RESRAD	RESidual RADiation (computer program)
RWMS	Radioactive Waste Management Site
TRI	triangular distribution
U	uniform distribution
USEI	United States Ecology Idaho, Inc.
USGS	United States Geological Survey
VOC	volatile organic chemical
WCS	Waste Control Specialists, LLC

1.0 Introduction

Neptune and Company, Inc. (Neptune), under contract to US Ecology Idaho, Inc. (USEI), has developed a computer model (the Grand View PA Model) to support decision making related to the disposal of radioactive waste at the USEI Resource Conservation and Recovery Act (RCRA) facility near Grand View, ID. The Grand View performance assessment (PA) Model assesses the long-term behavior of the waste disposal cells with respect to radioactive waste disposed. The Grand View PA Model is built using the GoldSim probabilistic systems analysis software. The modeling philosophy that underlies GoldSim is to approach modeling from the top down, keeping the modeling as simple as possible while including all of the important processes in the system. In general, inputs are presented as distributions, rather than as single, deterministic values, in order to capture the uncertainty in the system.

Input distributions for the Grand View PA Model are often taken from other PA modeling efforts to provide preliminary distributions for the Grand View PA Model. The other models include the Los Alamos National Laboratory (LANL) Area G PA Model that is undergoing development, the Clive DU PA Model from Clive, UT, the WCS PA Model from Andrews County, TX, and the Area 5 RWMS PA Model from the Nevada National Security Site. Some input distributions are informed by data presented in the Grand View Conceptual Site Model (CSM) (Neptune 2016). Other distributions are based on literature data or regulatory guidance and professional judgment.

There are inherent limitations when using analog data that are not site-specific. While reasonable efforts have been made to select applicable analogs, site-specific data would provide more informative results and might better identify sensitive parameters. If the results are sufficiently protective to support regulatory decision-making, this approach may be adequate. If particular performance criteria are unclear or unacceptable, or if the analogs are determined to be inapplicable, further site-specific parameter development may be warranted to reduce this uncertainty.

This document is organized similarly to the Grand View CSM (Neptune 2016) and is grouped according to containers and subcontainers within the Grand View PA Model.

A summary of general and transport parameter values and distributions used in the Grand View PA Model is provided in Table 1. Current inventory information is presented in Table 2 and discussed briefly in Section 5.3. Inventory used for Waste Acceptance Criteria is presented in Table 3 and discussed briefly in Section **Error! Reference source not found.**. Parameters related to the calculation of radiation dose are presented in Table 4 and are briefly discussed in Section 7.0. For distributions, the following notation is used:

- Small and Large are arbitrarily small and large numbers: 1×10^{-30} and 1×10^{30}, respectively.
- N(μ, σ, [min, max]) represents a normal distribution with mean μ and standard deviation, σ, and optional truncation at the specified minimum and maximum.
- LN(GM, GSD, [min, max]) represents a log-normal distribution with geometric mean GM and geometric standard deviation GSD, and optional truncation at the specified minimum and maximum.

- U(min, max) represents a uniform distribution with lower bound min and upper bound max.
- Beta(μ, σ, min, max) represents a generalized beta distribution with mean μ, standard deviation σ, and minimum and maximum values that specify the range of the distribution.
- G(μ, σ) represents a gamma distribution with mean μ and standard deviation σ.
- TRI(min, m, max) represents a triangular distribution with lower bound min, mode m, and upper bound max.
- DSC(*x*, *y*, … *z*) represents a discrete distribution of specific values.

Table 1. Summary of parameter values and distributions.

Parameter	Distribution	Units	Notes
Chronology			
institutional control	N(100, 10, 0, Large)	yr	Section 2.1
IC deterministic	dashboard input	yr	Section 2.1
Miscellaneous			
Small	1×10^{-30}	--	Section 2.2
Large	1×10^{30}	--	Section 2.2
Disposal Cell Dimensions			
Cell 14 Area	720 × 1,750	ft^2	Section 3.1
Cell 14 Volume	2,102,000	yd^3	Section 3.1
Cell 15 Area	768 × 2,260	ft^2	Section 3.1
Cell 15 Volume	4,800,000	yd^3	Section 3.1
Cell 16 Area	1,150 × 2,800	ft^2	Section 3.1
Cell 16 Volume	10,262,000	yd^3	Section 3.1
Waste Thickness	TRI(28.6, 33.6, 38.6)	m	Section 3.2
Initial Depth to Rad	3.6	m	Section 3.2
Initial RCRA Cover Thickness	3	ft	Section 3.3
Initial ET Cover Thickness	5	ft	Section 3.3
Top Soil Thickness	15	cm	Section 3.3
Upper Top Soil Thickness	U(1, 5)	cm	Section 3.3
Liner Thickness	3	ft	Section 3.3
Inert Fraction	U(0.25, 0.4)		Section 3.3
material property parameters			
ET Cover (also used for Top Soil)			
porosity	N(0.45, 0.015, 0.01, 1)	--	Section 4.1.1
particle density	N(2.65, 0.05, Small, Large)	g/mL	Section 4.1.1
RCRA Cover (also used for Top Soil)			
porosity	N(0.38, 0.018, 0.01, 1)	--	Section 4.1.2
particle density	same distribution as ET cover	g/mL	Section 4.1.2
Waste			
porosity	N(0.35, 0.017, 0.01, 1)	--	Section 4.1.3

Parameter	Distribution	Units	Notes
particle density	N(2.65, 0.05, Small, Large)	g/mL	Section 4.1.3
Clay Liner			
porosity	N(0.41, 0.013, 0.01, 1)	--	Section 4.1.4
particle density	N(2.70, 0.017, Small, Large)	g/mL	Section 4.1.4
water diffusivity			
C diffusivity	G(1.3×10^{-9}, 4.9×10^{-10})	m^2/s	Section 4.2.1.3
H diffusivity	G(2.0×10^{-9}, 2.0×10^{-9})	m^2/s	Section 4.2.1.3
I diffusivity	G(1.5×10^{-9}, 4.7×10^{-10})	m^2/s	Section 4.2.1.3
Ra diffusivity	G(9.9×10^{-9}, 3.3×10^{-10})	m^2/s	Section 4.2.1.3
Tc diffusivity	G(1.0×10^{-9}, 4.9×10^{-10})	m^2/s	Section 4.2.1.3
U diffusivity	G(7.4×10^{-10}, 2.9×10^{-10})	m^2/s	Section 4.2.1.3
generic water diffusivity (for all other elements)	G(1.1×10^{-9}, 5.3×10^{-10})	m^2/s	Section 4.2.1.3
air diffusion coefficient			
carbon	0.16	cm^2/s	Section 4.2.2.1
hydrogen	0.23	cm^2/s	Section 4.2.2.1
krypton	0.14	cm^2/s	Section 4.2.2.1
iodine	0.08	cm^2/s	Section 4.2.2.1
radon	0.12	cm^2/s	Section 4.2.2.1
radon emanation factor			
Radon EP Ratio	beta(0.26, 0.11, 0, 1)	--	Section 4.2.2.1
geochemistry			
Kd (soil / water partition coefficients)			
clay liner (Note that the distributions with the "_dist" suffix are modified after sampling in the model to set negative values to be 0 mL/g)			
Ar, Kr, Rn	0	mL/g	Section 4.2.1.1
Am	LN(4.8×10^{3}, 1.4)	mL/g	Section 4.2.1.1
C_dist	N(1.1, 0.98, -0.6, Large)	mL/g	Section 4.2.1.1
I_dist	N(2.9, 2.3, -0.13, Large)	mL/g	Section 4.2.1.1
Np	LN(55, 3.8)	mL/g	Section 4.2.1.1
Pu	LN(5.1×10^{3}, 2.1)	mL/g	Section 4.2.1.1
Ra	N(6.1×10^{4}, 5.6×10^{4}, 12, Large)	mL/g	Section 4.2.1.1

Parameter	Distribution	Units	Notes
Tc_dist	N(0.25, 0.34, -0.15, Large)	mL/g	Section 4.2.1.1
U	N(430, 390, 1.2, Large)	mL/g	Section 4.2.1.1
low generic Kd (Cl)	LN(0.3, 5.4)	mL/g	Section 4.2.1.1
medium generic Kd (Ca, H)	LN(14, 2.5)	mL/g	Section 4.2.1.1
high generic Kd (Ac, Ag, Ba, Cm, Co, Cs, Eu, K, Nb, Ni, Pa, Pb, Sm, Sn, Sr, Th)	LN(710, 7.9)	mL/g	Section 4.2.1.1
cover material and waste (Note that the distributions with the "_dist" suffix are modified after sampling in the model to set negative values to be 0 mL/g)			
Ar, Kr, Rn	0	mL/g	Section 4.2.1.1
Am	N(2.1×10^{3}, 870, 12, Large)	mL/g	Section 4.2.1.1
C_dist	N(2.4, 0.99, -0.39, Large)	mL/g	Section 4.2.1.1
I_dist	N(3.3, 1.1, -0.03, Large)	mL/g	Section 4.2.1.1
Np	N(81, 63, 0.063, Large)	mL/g	Section 4.2.1.1
Pu	N(640, 170, 10, Large)	mL/g	Section 4.2.1.1
Ra	N(6.5×10^{3}, 6.6×10^{3}, 1.3, Large)	mL/g	Section 4.2.1.1
Tc_dist	N(0.098, 0.083, -2.8, Large)	mL/g	Section 4.2.1.1
U	N(9.2, 4.2, 0.014, Large)	mL/g	Section 4.2.1.1
low generic Kd (Cl)	LN(0.72, 4.2)	mL/g	Section 4.2.1.1
medium generic Kd (Ca, H)	LN(6.9, 4.0)	mL/g	Section 4.2.1.1
high generic Kd (Ac, Ag, Ba, Cm, Co, Cs, Eu, K, Nb, Ni, Pa, Pb, Sm, Sn, Sr, Th)	LN(250, 12)	mL/g	Section 4.2.1.1
solubility			
H, Kr, Rn	no solubility limit		Section 4.2.1.2
Am	LN(1.4×10^{-6}, 120)	mol/L	Section 4.2.1.2
C	LN(7.5×10^{-3}, 8.2)	mol/L	Section 4.2.1.2
I	LN(2.2, 3.8)	mol/L	Section 4.2.1.2

Parameter	Distribution	Units	Notes
Np	LN(3.2×10^{-6}, 32)	mol/L	Section 4.2.1.2
Pu	LN(1.4×10^{-7}, 100)	mol/L	Section 4.2.1.2
Ra	LN(3.2×10^{-7}, 12)	mol/L	Section 4.2.1.2
Tc	LN(2.2, 3.8)	mol/L	Section 4.2.1.2
U	LN(5.0×10^{-5}, 39)	mol/L	Section 4.2.1.2
generic distribution for all other elements	LN(3.0×10^{-5}, 350)	mol/L	Section 4.2.1.2
Henry's Law constants			
$K_{H,0}$ dimensionless			
C	N (1.2, 0.086, 0, Large)	--	Section 4.2.2
H	N (($-2.04\times10^{-4} + 7.53\times10^{-7} \times T^{b}$), 2.68×10^{-6}, 0, Large)	--	Section 4.2.2
I	N (0.076, 0.14, 0, Large)	--	Section 4.2.2
Kr	N (16, 0.34, 0, Large)	--	Section 4.2.2
Rn	N (4.3, 0.73, 0, Large)	--	Section 4.2.2
K_H temperature coefficient			
C	2380	K	Section 4.2.2
I	1838	K	Section 4.2.2
Kr	4400	K	Section 4.2.2
Rn	2780	K	Section 4.2.2
air transport parameters			
atmosphere thickness	2	m	Section 6.1
wind speed	N (4.5, 0.5, Small, Large)	m/s	Section 6.1
atmosphere mixing height	N (2.0, 0.5, Small, Atmosphere_Thickness)	m	Section 6.1
atmosphere diffusion length	N (0.1, 0.02, Small, Large)	m	Section 6.1
resuspension flux	U (2.5×10^{-7}, 0.3)	kg/m^2-yr	Section 6.1
water transport parameters			
saturation			
ET Cover	N(0.35, 0.033, 0.01, 1)	--	Section 6.2.2
RCRA Cover	Same value as ET Cover	--	Section 6.2.2
Waste	N(0.6, 0.033, 0.01, 1)	--	Section 6.2.2
Liner	N(0.925, 0.083, 0.01, 1)	--	Section 6.2.2

Parameter	Distribution	Units	Notes
saturation			
Exponents, water tortuosity	1000 paired data entries for water content and porosity exponents	--	Section 6.2.2
Exponent selector	randomly chooses a number between 1 and 1000		Section 6.2.2
erosion transport parameters			
sheet erosion RCRA	N (0.9, 0.14, Small, Large)	Mg/ha-yr	Section 6.3
sheet erosion ET	N (1.0, 0.27, Small, Large)	Mg/ha-yr	Section 6.3
wind erosion	N (0.67, 0.06, Small, Large)	Mg/ha-yr	Section 6.3
plant parameters			
biomass production rate	N (267, 114, Small, Large)	g/m^2-yr	Section 6.4.1
PctCover_Plot*_[plant]	Tabulated in the model	—	Section 6.4.1
Percent cover random selector	randomly select between values 1 to 1000, inclusive	—	Modeling construct
Vegetation Type Picker	Discrete (1, 2, 3, 4)	—	Section 6.4
greasewood parameters			
RootShoot_Ratio	U(0.30, 1.24)	—	Section 6.4.1
MaxDepth	570	cm	Section 6.4.1
b—fitting parameter for root shape	N(14.6, 0.0807, 1, Large)	—	Section 6.4.1
grass parameters			
RootShoot_Ratio	T(1, 1.2, 2)	—	Section 6.4.1
MaxDepth	150	cm	Section 6.4.1
b—fitting parameter for root shape	N(2.19, 0.036, 1, Large)	—	Section 6.4.1
forb parameters			
RootShoot_Ratio	U(0.40, 1.80)	—	Section 6.4.1
MaxDepth	51	cm	Section 6.4.1
b—fitting parameter for root shape	N(23.9, 0.313, 1, Large)	—	Section 6.4.1
other shrub parameters			
RootShoot_Ratio	U(0.40, 1.8)	—	Section 6.4.1
MaxDepth	110	cm	Section 6.4.1
b—fitting parameter for nest shape	N(23.9, 0.313, 1, Large)	—	Section 6.4.1
plant/soil concentration ratios			
PlantCRs by chemical element	tabulated in the model	—	Section 6.4.1

Parameter	Distribution	Units	Notes
SA_wvH	1	—	Section 6.4.1
water_to_H	N(9, 0.01, Small, Large)	—	Section 6.4.1
f_Hv	N(0.1, 0.01, Small, 1-Small)	—	Section 6.4.1
CF_plant_carbon	N(0.7, 0.01, Small, Large)	—	Section 6.4.1
GravWaterContent_H3	N(0.1, 0.01, Small, 1-Small)	—	Section 6.4.1
animal parameters			
ant transport parameters			
Volume of Each Nest	N(μ=0.161, σ=0.024, min=0, max=Large)	m^3	Section 6.4.2
Lifespan of Each Colony	N(μ=20.2, σ=3.6, min=0, max=Large)	yr	Section 6.4.2
ColonyDensity - area density of colonies on the ground:			
ColonyDensity_Plot1	G (33,1, min=0, max=Large)	1/ha	Section 6.4.2
ColonyDensity_Plot2	G (7, 1, min=0, max=Large)	1/ha	Section 6.4.2
ColonyDensity_Plot3	G (17, 1, min=0, max=Large)	1/ha	Section 6.4.2
ColonyDensity_Plot4	G (6, 1, min=0, max=Large)	1/ha	Section 6.4.2
MaxDepth—maximum depth for any colony	212	cm	Section 6.4.2
b—fitting parameter for nest shape	N(μ=10, σ=0.71, min=1, max=Large)	—	Section 6.4.2
mammal transport parameters			
MoundDensity—area density of mounds on the ground:			
_Plot1	G (235, 1, min=0, max=Large)	1/ha	Section 6.4.2
_Plot2	G (1.33, 1, min=0, max=Large)	1/ha	Section 6.4.2
_Plot3	G (1.33, 1, min=0, max=Large)	1/ha	Section 6.4.2
_Plot4	G (1.33, 1, min=0, max=Large)	1/ha	Section 6.4.2
ExcavationRate—volumetric rate of a single burrow excavation	N(μ=0.0006, σ=0.00015, min=Small, max=Large)	m^3/yr	Section 6.4.2
MaxDepth—maximum depth for any burrow	200	cm	Section 6.4.2
b—fitting parameter for burrow shape	N(μ=4.5, σ=0.84, min=1, max=Large)	—	Section 6.4.2

Table 2. Summary of Current Inventory included in the Grand View PA Model.[1]

Modeled Radionuclide	Disposed Inventory 2000–2009	Disposed Inventory 2010–2015	Units
H3	1.56E+01	2.84E+01	Ci
C14	1.02E-04	1.81E-02	Ci
Cl36	4.00E-08	6.20E-08	Ci
K40	2.23E-08	6.01E+00	Ci
Ca41	0	0	Ci
Co60	1.88E-03	4.46E-01	Ci
Ni59	0	1.04E-04	Ci
Ni63	9.00E-08	2.12E-01	Ci
Kr85	1.11E-02	1.02E-01	Ci
Sr90	4.45E-01	5.27E-01	Ci
Nb93m	0	0	Ci
Nb94	0	1.23E-04	Ci
Tc99	1.74E-07	1.14E+00	Ci
Ag108m	0	2.42E-04	Ci
Sn121m	1.00E-08	0	Ci
I129	2.00E-08	1.10E-06	Ci
Cs135	0	0	Ci
Cs137	1.52E-01	2.29E-01	Ci
Ba133	6.70E-05	8.45E-06	Ci
Sm151	7.00E-06	0	Ci
Eu152	1.70E-07	7.79E-02	Ci
Eu154	9.00E-08	5.28E-03	Ci
Pb210	2.00E+01	7.37E-01	Ci
Rn222	0	0	Ci
Ra226	2.49E+01	2.44E+01	Ci
Ra228	1.03E+01	4.56E+00	Ci
Ac227	0	6.54E-05	Ci
Th228	1.70E-03	2.13E-02	Ci
Th229	0	0	Ci
Th230	1.61E+02	3.69E+00	Ci
Th232	1.22E+01	2.04E+01	Ci
Pa231	0	0	Ci
U233	0	0	Ci
U234	1.66E+01	1.28E+01	Ci

Modeled Radionuclide	Disposed Inventory 2000–2009	Disposed Inventory 2010–2015	Units
U235	8.64E-01	1.31E+00	Ci
U236	0	0	Ci
U238	3.81E+01	3.44E+01	Ci
Np237	0	0	Ci
Pu238	0	2.06E-03	Ci
Pu239	0	4.13E-04	Ci
Pu240	0	3.83E-04	Ci
Pu241	0	1.46E-02	Ci
Pu242	0	0	Ci
Pu244	0	0	Ci
Am241	1.51E-01	1.40E+00	Ci
Am243	0	0	Ci
Cm243	0	1.92E-04	Ci
Cm244	0	1.92E-04	Ci
Cm245	0	0	Ci
Cm246	0	0	Ci
Cm247	0	0	Ci
Cm248	0	0	Ci

[1] Two different time periods are delineated for current inventory: 2000-2009 and 2009-2015. These correspond to the time periods when radioactive waste was buried no closer to the surface than 3.6 m versus no closer to the surface than 6 m. More information is provided in Section 5.3.

Table 3. Summary of Safety Basis Inventory included in the Grand View PA Model.

Modeled Radionuclide	Safety Basis Inventory*	Units	Safety Basis Inventory converted†	Units
H3	1000	pCi/g	31000	Ci
C14	10	pCi/g	310	Ci
Cl36	0	pCi/g	0	Ci
K40	800	pCi/g	25000	Ci
Ca41	25	pCi/g	770	Ci
Co60	25	pCi/g	770	Ci
Ni59	25	pCi/g	770	Ci
Ni63	25	pCi/g	770	Ci
Kr85	0	pCi/g	0	Ci
Sr90	25	pCi/g	770	Ci
Nb93m	25	pCi/g	770	Ci
Nb94	25	pCi/g	770	Ci
Tc99	1	pCi/g	31	Ci
Ag108m	25	pCi/g	770	Ci
Sn121m	0	pCi/g	0	Ci
I129	0.01	pCi/g	0.31	Ci
Cs135	25	pCi/g	770	Ci
Cs137	25	pCi/g	770	Ci
Ba133	25	pCi/g	770	Ci
Sm151	25	pCi/g	770	Ci
Eu152	25	pCi/g	770	Ci
Eu154	25	pCi/g	770	Ci
Pb210	333	pCi/g	10000	Ci
Rn222	0	pCi/g	0	Ci
Ra226	112	pCi/g	3500	Ci
Ra228	28	pCi/g	860	Ci
Ac227	3.2	pCi/g	99	Ci
Th228	28	pCi/g	860	Ci
Th229	28	pCi/g	860	Ci
Th230	83	pCi/g	2600	Ci
Th232	28	pCi/g	860	Ci
Pa231	3.2	pCi/g	99	Ci
U233	3.3	pCi/g	100	Ci

Modeled Radionuclide	Safety Basis Inventory*	Units	Safety Basis Inventory converted†	Units
U234	83	pCi/g	2600	Ci
U235	3.3	pCi/g	100	Ci
U236	3.2	pCi/g	99	Ci
U238	83	pCi/g	2600	Ci
Np237	0.1	pCi/g	3.1	Ci
Pu238	0.1	pCi/g	3.1	Ci
Pu239	0.1	pCi/g	3.1	Ci
Pu240	0.1	pCi/g	3.1	Ci
Pu241	0.1	pCi/g	3.1	Ci
Pu242	0.1	pCi/g	3.1	Ci
Pu244	0.1	pCi/g	3.1	Ci
Am241	0.1	pCi/g	3.1	Ci
Am243	0.1	pCi/g	3.1	Ci
Cm243	0.1	pCi/g	3.1	Ci
Cm244	0.1	pCi/g	3.1	Ci
Cm245	0.1	pCi/g	3.1	Ci
Cm246	0.1	pCi/g	3.1	Ci
Cm247	0.1	pCi/g	3.1	Ci
Cm248	0.1	pCi/g	3.1	Ci

* from "USEI Site B RESRAD Input Parameter Summaries_EGL2005_07012015.xlsx"

† converted from the SB concentration by using deterministic modeled variables (e.g., bulk density, volume of disposal cell) to estimate total activity if the entire waste volume was filled with the SB inventory.

Table 4. Summary of Dose Model Parameters.

Parameter	Units	Determi-nistic value	Stochastic Value	GoldSim ID	Source	Page/Table	Notes
Air transit time; residence	min	27		AirExchangeRate_Building	EPA 2012	Sec 5.1, p. 50	Used for gas inhalation indoors (Rn222). Based on an air exchange rate of 0.45/hr. Used in residential scenario
Body mass normalized, age 6-70 (beef)	kg	67.80		BodyWeightIng_Beef	EPA 2011; Calcs in *USEI Dose Info.xlsx* in the 'Ingestion rates' worksheet	Table 13-33, p 13-42	Normalized body mass for beef intake by ages 6-70. Pop avg body weights extracted from: Table 8-3, p.12, EPA 2011
Body mass normalized; age 6-70 (game)	kg	64.22		BodyWeightIng_Game	EPA 2011; Calcs in *USEI Dose Info.xlsx* in the 'Ingestion rates' worksheet	Table 13-41, p 13-50	Normalized body mass for game intake by ages 6-70. Pop avg body weights extracted from: Table 8-3, p.12, EPA 2011
Body mass normalized; age 6-70 (vegetables)	kg	69.32		BodyWeightIng_Veg	EPA 2011; Calcs in *USEI Dose Info.xlsx* in the 'Ingestion rates' worksheet	Table 13-10, p 13-19	Normalized body mass for veg intake by ages 6-70. Pop avg body weights extracted from: Table 8-3, p.12, EPA 2011

Parameter	Units	Determi-nistic value	Stochastic Value	GoldSim ID	Source	Page/Table	Notes
Body mass, antelope	kg	Median used	U(42, 59)	BodyMass_Antelope	SDZG 2009	Sec. ‘Physical Characteristics’	Distribution based on range for mass of male antelopes.
Borehole, depth	ft	290		Borehole_Depth	USEI CSM		Depth includes embankment elevation, thickness of unsaturated zone, and thickness of upper aquifer.
Borehole, diameter	in	8		BoreholeDiameter	NRC 1986	Sec. 4.2.1	Diameter of the drilled borehole for a water well.
Concentration ratios, produce: soil	Bq/g dry plant / Bq/g soil	See Grand View PA Model CT model container: ‘plant parameters’		CR_Elements_DryProduce CR_DryProduce	NUREG/CR-5512	Extracted from Transport model	Residential scenario.
Conversion factor; dry to wet produce	g dry plant / g wet plants	0.11	Trunctated N(0.11, 0.016, Small, 1-Small)	DryWetConversion _Produce	EPA 2011	Calcs in *USEI Dose info.xlsx* ‘Dry-wet ratio sheet’	Calculations specific to produce for Idaho gardens. Moisture content from Table 9-37 EPA 2011
Dose conversion factor; Kr-85 inhalation	Sv/Bq d m^{-3}	2.2E-11		DCF_Kr85	ICRP 2012;	Annex C Table C1, p.61.	This is not the final DCF for Kr85; Calcs in GS DCF container
Dose conversion factor; Rn222 inhalation	Sv/Bq	1.77E-09		DCF_Radon	ORNL 2017	Table 1	

Parameter	Units	Determi-nistic value	Stochastic Value	GoldSim ID	Source	Page/Table	Notes
Dose conversion factor; Rn222 progeny inhalation	Sv/Bq	2.46E-08		DCF_RadonProgeny	ORNL 2017	Table 1	Sum for Po218, Pb214, and Bi214
Dose conversion factors; external, soil	Sv/Bq s m^3	See *USEI dose info.xlsx* ‘DCFs’		DCF_Ext_RESRAD	RESRAD v7.2; ICRP 107 library; DOE STD 1196-2011 Ref. Person	Rollup Calcs in *USEI dose info.xlsx;* ‘DCFs’	For an infinite dimension soil source. Used in all scenarios involving external exposure
Dose conversion factors; ingestion	Sv/Bq	See *USEI dose info.xlsx* ‘DCFs’		DCF_Ing_RESRAD	RESRAD v7.2; ICRP 107 library; DOE STD 1196-2011 Ref. Person	Rollup Calcs in *USEI dose info.xlsx;* ‘DCFs’	Used in all scenarios involving ingestion
Dose conversion factors; inhalation	Sv/Bq	See *USEI dose info.xlsx* ‘DCFs’		DCF_InhDust_RESRAD	RESRAD v7.2; ICRP 107 library; DOE STD 1196-2011 Ref. Person	Rollup Calcs in *USEI dose info.xlsx;* ‘DCFs’	Excluding krypton and radon. Used in all scenarios involving inhalation
External dose conversion factors; modifying factors	n/a	See *USEI_DCF_ModFactors.xlsx*		Container: DCF_Ext_Modifiers	RESRAD v7.2; ICRP 107 library; DOE STD 1196-2011 Ref. Person		DCF modifying factors for open pit, closed pit, and varying soil/cover soil thicknesses.
Exposure area, cattle	ac	364	LN(112, 4.54, 143, Large)	RanchArea	site-specific distribution		Used Idaho state-wide data; see Section 7.2 below

Parameter	Units	Determi-nistic value	Stochastic Value	GoldSim ID	Source	Page/Table	Notes
Exposure area, antelope	acre	Median	U(995, 9192)	HomeRange_Antelope	Huffman 2004		Foraging distances for summer and winter were equally weighted and assigned as diameters of a circular home range, from 0.1 to 0.8 km in the spring and summer to 3.2 to 9.7 km in the fall and winter.
Exposure frequency, resident	hr/yr	7900	N(7900, 100, 7500, 8766)	TimeFraction_Resident	EPA 2011	Table 16-1; 16-22; Calcs in *USEI Dose Info.xlsx* 'Inhalation Rates'	See Excel worksheet for explanation on calculations. Exposure frequency is sum of outdoor and indoor fractions rounded.
Exposure frequency; outdoor, resident	hr/yr	800	N(800, 80, 600, 1000)	TimeFraction_Res _Outdoor	EPA 2011	Table: 16-22; Calcs in *USEI Dose Info.xlsx* 'Inhalation Rates'	Standard deviation is 10% of the mean.
Exposure frequency; indoor, resident	hr/yr	7100		TimeFraction_Res _Indoor	EPA 2011	Table 16-1; Calcs in *USEI Dose Info.xlsx* 'Inhalation Rates'	Note the value in the Grand View PA Model is different than that in the Excel sheet due to rounding and using functions in GoldSim.
Exposure frequency; garden, resident	—	0.5	TRI(0.25, 0.5, 0.75)	OutdoorFraction_Res _Garden	Professional judgment		Fraction of time spent in the garden.

Parameter	Units	Determi-nistic value	Stochastic Value	GoldSim ID	Source	Page/Table	Notes
Exposure frequency; mud pit, garden, resident	—	0.1		TimeFract_Gardner_MudPit	Professional judgment		Assumed that the garden is directly over the mud pit 10% of the time.
Exposure time; construction worker	—	0.1643	N(0.1643, 0.01825, Small, 1-Small)	TimeFraction_Constres	UCSB 2015		Assumed 8 hour workday; +/- a month of work days.
Exposure time; driller	—	9.126E-04	N(9.126E-4, 2.282E-4, Small, 1-Small)	TimeFraction_Driller	NRC 1986	Sec 4.2.1	Takes a driller approximately 1 day to drill the well.
Exposure time; rancher	—	0.1186	N(0.1186, 9.126E-3, Small, 1-Small)	TimeFraction_Rancher	Fiasco 2010, MCC 2007		Professional judgment. Assumed out on the range for mainly the summer months.
Exposure time; recreation	hr/yr	15	DSC((0.75, 5), (0.15, 15), (0.075, 25), (0.025, 35))	TimeExposure_Rec	Professional judgment		Discrete distribution based on bins of 10.
Exposure time fraction; OHV	—	median	U(0.1, 0.2)	TimeFraction_OHV	Professional judgment		Used in both recreation and ranching scenarios.
Exposure time fraction; Construction, basement	—	median	N(0.1, 0.03, Small, 1-Small)	TimeFract_Constres_Bsmnt	Professional judgment		Fraction of time assigned to exposure to excavated material if basement construction is assessed.

Parameter	Units	Deterministic value	Stochastic Value	GoldSim ID	Source	Page/Table	Notes
Fraction C in forage	g C/ g wet mass plant	0.09	N(0.09, 0.01, Small, 1-Small)	f_C_forage	NRC 1992	Table C.1	Used in scenarios involving beef/game ingestion.
Fraction H in forage	g H / g wet mass plant	0.1	N(0.1, 0.01, Small, 1-Small)	f_H_forage	NRC 1992	Table D.1	Used in scenarios involving beef/game ingestion.
Gamma attenuation factors; indoors	n/a	0.4	N(0.4, 0.04, Small, 1-Small)	IndoorGammaFactor	EPA 2000	Eqn 4, p 2-22	Assumes a 6” slab of shielding from the foundation. Multiplier to address reduction in external dose due to shielding.
Ingestion rate; beef	g/kg of body weight/d	2.45	N(2.45, 0.15, Small, Large)	Consumption_Beef	EPA 2011	Table 13-33, p. 13-42	Ingestion rate of beef for rancher scenario.
Ingestion rate; forage, cattle	kg dry weight plant/d	11.8	U(8.85, 14.75)	ForageIngestionRate_Cattle	EPA 2005	Table B-3-10, B-138 (variable ‘Qpi’)	Min/max are +/- 25% of recommended value. Forage ingestion rates for beef cattle.
Ingestion rate; forage, game	kg/d	0.577×(BodyMassFactor_Antelope)$^{0.727}$ × 0.001 kg/day		ForageIngestionRate_Antelope	EPA 1993	Eqn. 3-9, p. 3-6	Allometric equation used to calculate the forage ingestion rate for antelope/game.
Ingestion rate; game	g/kg of body mass/d	0.97	N(0.97, 0.06, Small, Large)	Consumption_Game	EPA 2011	Table 13-41, p. 13-50	Ingestion rate of game for recreation scenario.

Parameter	Units	Determi-nistic value	Stochastic Value	GoldSim ID	Source	Page/Table	Notes
Ingestion rate; soil, adult	mg/d	100	TRI(20, 50, 100)	IngestionRate_Soil	EPA 2011, EPA 2014	2011: Table 5-1, p. 5-5; 2014: Attachment 1	Ingestion rate of soil for resident, construction worker, rancher, and recreation scenarios.
Ingestion rate; soil, cattle	kg/d	0.05	U(0.05, 0.95)	SoilIngestionRate_Cattle	EPA 2005	Table B-3-10, p. B-139 (variable 'Qs')	Ingestion rate of soil for cattle. Range is +/- 100%
Ingestion rate; soil, game	kg/d	0.005	U(0.005, 0.095)	SoilIngestionRate _Antelope	Professional Judgment		10% of ingestion distribution of cattle based upon relative body mass.
Ingestion rate; soil, resident	mg/d	125	N(70, 10, Small, Large)	IngestionRate_Soil_Res	EPA 2011	Table 5-1, p. 5-5; Calcs in *USEI Dose info.xlsx* 'Soil Ingestion' worksheet	Deterministic value was determined by age-weighting from ages 1 to < 21 yr. Stochastic from calculations using general population central tendency.
Ingestion rate; vegetable	g/kg of body mass/d	2.08	N(2.08, 0.07, Small, Large)	Consumption_Veg	EPA 2011	Table 13-10, p. 13-19	Ingestion rate of vegetables. Source includes fruits like squashes, tomatoes, etc. in this category.
Inhalation rate; general	m^3/min	0.026	TRI(0.012, 0.026, 0.05)	InhalationRate_General	EPA 2011	ES-1 short term inhalation, p. xiii	Ages 21-31 short term inhalation rates used for light, moderate, and high intensity, respectively.

Parameter	Units	Determi-nistic value	Stochastic Value	GoldSim ID	Source	Page/Table	Notes
Inhalation rate; resident	m^3/d	14.73	N(14.73, 1.473, Small, Large)	InhalationRate_Resident	EPA 2011	Table 6-1; Calcs in *USEI dose info.xlsx* 'Inhalation Rates'	Long-term inhalation rates used for resident. Calculations weighted to age.
Mud pit, area	ft^2	72		MudPitArea	NRC 1986	Sec. 4.2.1	Area of mud pit for water well
Mud pit, depth	ft	4		MudPit_Depth	NRC 1986	Sec. 4.2.1	Mean depth of mud pit for water well
Off-highway vehicle (OHV) dust loading	—	98.1	LN(98.1, 1.65)	OHV_DustLoading	EPA 2008	Table 2	Multiplier for ambient dust concentration in the air from OHVs (activity based).
Preparation loss; meat	%	29.7		PrepLoss_Meat	EPA 2011	Table 13-69, p. 13-81	Mean net preparation/cooking loss from food preparation for meats.
Post-cooking loss; meat	%	29.7		PostCookLoss_Meat	EPA 2011	Table 13-69, p. 13-81	Mean net post-cooking loss from food preparation for meats.
Radon-222 indoor progeny equilibrium factor (*F*)	—	0.4	DSC(1, 0.4)	ProgenyEqmFactor _Rn222_Indoor	ICRP 2010	Glossary, p. 22	
Soil-gas indoor air ratio (alpha, residence)	—	0.0023	Beta(0.0023, 0.0012, 0, 1)	Alpha_Residence	site-specific distribution		Section 7.1 below

Parameter	Units	Determi-nistic value	Stochastic Value	GoldSim ID	Source	Page/Table	Notes
Transfer factors; forage-to-animal	d/kg	See *USEI dose info.xlsx* ‘TF Beef + Game’		RanchedBeef_TF; Antelope_TF	ANL 2015	Table 6.4.2, p.174	Note: read Sec 6.4.3 to understand how values were chosen (essentially by year).

2.0 Chronology and Settings

2.1 Model Chronology

The Model Chronology container includes one stochastic distribution for institutional control. As has been done in previous PAs, the institutional control distribution has a mean of 100 years, the typical regulatory time frame for institutional control. The standard deviation is chosen to be 10 years. The minimum is set at 0 years, and the maximum is set to an arbitrarily large number.

The Model also allows the user to choose a deterministic value for institutional control via the Control Dashboard.

2.2 Simulation Settings

The Model includes a variety of simulation settings in the Miscellaneous container for choosing between different inventory and contaminant transport options. Most of the contaminant transport settings are for diagnostic purposes.

Also in this container, the values for Small and Large are defined to enable consistent truncation of distributions at small, non-zero values or large values (effectively no truncation at the large end). GoldSim requires a maximum value if a minimum value is chosen for a distribution and vice versa.

Switches are defined in the Switches subcontainer. These parameters allow the user to choose between different modeling options, such as inventory and cover design, and allow the user to turn on and off different processes and features. Turning off processes and features is helpful for model diagnostics.

3.0 Disposal Site Characteristics

The Grand View PA Model simulates contaminant transport for each of the three disposal cells—Cells 14, 15, and 16—with different 1-D contaminant transport columns. Discretization of the modeling columns was chosen by running Neptune's discretization diffusion model, which allows the modeler to choose a number of modeling cells in the column that minimizes numerical dispersion. The Model assumes the three disposal cells have the same waste depth but allows for different areas and, indirectly, volumes. Only the top slope characteristics of the disposal cell were included; the side slopes were not modeled, except by including their areas in the total area of the disposal cell.

Dimensions and other physical characteristics of the Site are defined in the Transport container. Waste cell volumes and areas are in each of the different disposal cell containers in the Cell Dimensions container. These areas are used in the Model as a part of receptor scenarios and in defining the transport column areas.

3.1 Areas and Volumes

Total waste volumes and areas were taken from Table D-3, Landfill Capacities, in the file *2054_001 Capacities.pdf*, with the exception of area for Cell 14. We used Google Earth to estimate the width dimension of Cell 14, with an average width of about 720 ft, which is slightly narrower than that dimension in Table D-3. The length of Cell 14, 1,750 ft, was taken from Table D-3. Cell design volume is not used directly in the model calculations.

3.2 Waste Thickness

Depth of the disposal cells is assumed to be an average depth across the entire volume of the disposal cell. The depth of the disposal cells was assumed to be the same and was taken to be 33.6 m. This value was taken from the RESRAD input file (USEI 2015). Because we did not use site data to inform the preliminary distribution, a triangular distribution was chosen with 33.6 m being the most likely value, plus or minus 5 m, resulting in 28.6 m as the minimum, and 38.6 m as the maximum to reflect uncertainty and variability in the waste depth.

Initial depth to radioactive waste is a parameter used in the Model for the minimum initial depth to radioactive waste before erosion occurs. This depth is assigned to 3.6 m and is used in the Model to obtain the initial cover and select waste depths combined. For Cell 16, which does not have radioactive waste placed closer than 6 m to the surface (i.e., in Cell 16 radioactive waste is at least 6 m below the ground surface), modeled waste inventory was set to zero in the upper modeled waste cell layers. Waste layers in the Model are assumed to have the same material properties whether or not the waste is radioactive material.

To summarize, initial depth to radioactive waste is set at 3.6 m for all disposal cells. This simplifies the Model by having all disposal cells on the same discretization scheme. However, in Cell 16 there is no radioactive waste buried above 6 m.

3.3 Other Disposal Cell Properties

The initial thickness of the RCRA cover is set at 3 ft, and the initial thickness of the evapotranspiritive (ET) cover is set at 5 ft, as described in the CSM. To support dose calculations, the top soil depth is set at 15 cm total. The top soil is discretized into two cells, with the top cell having a variable depth of 1 to 5 cm. The top soil layer is critical as inputs to the dose model. A depth of around 1 cm is often used. However, sometimes depths up to 5 cm are also used. The depth of the uppermost layer was modeled as a uniform distribution from 1 to 5 cm, with a deterministic value of 1 cm.

The clay liner thickness is set at 3 ft. This layer is below the waste layer, at the bottom of the disposal cell.

The inert fraction represents the fraction of gravel in the top soil layers of the ET cover, as indicated in the CSM (Neptune 2016). The amount of gravel in the ET cover is prescribed to be 25 to 40% by weight (DBSA 2011), so the inert fraction was given a uniform distribution from 0.25 to 0.4. There was no inert fraction added to the RCRA cover.

4.0 Materials

4.1 Material Properties

Material property distributions for porosity, particle density, and water saturation came from data collected for the ET cover (DBSA 2010; DBSA 2011) and from an informal expert elicitation with USEI and Neptune personnel (conference call with Paul Black, Katie Catlett, Mike Sully, Vaughn Thurgood, and Justin Jensen, May 24, 2017). Ranges of values were discussed and chosen for many of the materials. Unless otherwise noted, the ranges were translated to distributions by interpreting them as representing three standard deviations from the mean—in other words, representing the 1st and 99th percentiles of the distribution. The rationale behind the distributions is summarized below by type of material. Water saturation distributions and discussion are presented in Section 6.2 below.

The minimum and the maximum were chosen for all of these distributions to exclude values deemed implausible based on the professional judgment of Neptune scientists, and to be consistent with other PA models. The sections below summarize the discussion and the information shared at the meeting.

4.1.1 ET Cover

Data were selected from DBSA (2010) that represent the most likely soils to be used in an ET cover, both as built and as the cover evolves over time: TP-13, TP-14, and TP-15, with 80% and 92% compactions (DBSA 2010; DBSA 2011). The average porosity of the data is used as the mean of the distribution. The standard deviation was chosen using professional judgment of plausible values that could represent average porosity over the cover and over time.

Particle density of the ET cover is expected to be about 2.65 g/cm^3, based on the alluvial sediments on the Site, which are similar in density to quartz. The standard deviation was chosen so that two standard deviations included 2.75 g/cm^3.

4.1.2 RCRA Cover

The RCRA cover does not have a function or process in the current Model to represent the high-density polyethylene (HDPE) liner and geosynthetic clay liner that are at the bottom of the cover and that are ostensibly effective radon barriers, perhaps for as much as a few hundred years. To more closely model that function, the Model could include a no-flux boundary between the RCRA cover and the top layer of waste to account for the protective layers and liners in the cover, until a point in time when the engineered system is assumed to be not as effective. This no-flux boundary would prevent gaseous diffusion and aqueous diffusion.

Because the current Model does not include a no-flux barrier (to represent the HDPE liner and geosynthetic clay liner), it may overstate gaseous diffusion to the atmosphere and aqueous diffusion. However, by overstating infiltration, the Model may also understate radon emanation since additional moisture content in the cover and waste layers will retard radon emanation.

The RCRA cover material is likely to include a greater sand fraction than the highly specified silty material of the ET cover because of availability and composition of local material. More coarse-grained material results in a lower porosity. The range of likely porosity is 0.32 to 0.43, with a mean of about 0.38 and a corresponding standard deviation of 0.018.

The particle density of the RCRA cover is assumed to have the same distribution as the ET cover.

4.1.3 Waste

Large-scale average data of the density of the waste have been gathered for the duration of disposal operations. Annual data can vary, depending on waste streams that have been accepted and disposed, and long-term averages over space and time show trends. Current cumulative wet density is about 115 lbm/ft^3 overall, with Cell 15 at a large-scale density of 109 lbm/ ft^3 and Cell 16 at 105 lbm/ ft^3. This average corresponds to about 100 lbm/ ft^3 terms of a dry-weight density and a porosity of 0.35. This results in an estimated porosity range of 0.3 to 0.4, with a standard deviation of 0.017.

Particle density is assumed to have the same distribution as the cover but should be slightly wider, with a standard deviation of 0.05.

Using these distributions, the Model uses a mean value of 1.7 g/cm^3 for bulk density, based on particle density and porosity of waste. This value is slightly higher than what was used in the RESRAD model for "density of the contaminated zone" of 1.5 g/cm^3.

4.1.4 Liner

Data from the clay liner below the waste is gathered regularly during construction to comply with regulations. The liner porosity average is 0.41 based on estimates from construction records. The range of clay liner porosity is 0.37 to 0.43.

Similarly, particle density measurements of the clay for the liner come from construction records, with a mean of 2.7 g/cm^3 and a range of 2.65 to 2.75 g/cm^3, and a corresponding standard deviation of 0.017 g/cm^3.

4.2 Geochemistry

4.2.1 Water

4.2.1.1 Kd

Soil-water partition coefficients (K_ds) were chosen for the Grand View PA Model from a previously developed PA model with similar materials and geochemical conditions (e.g., pH).

For clay material in the Grand View PA Model, K_d distributions were taken from the WCS PA Model for clay material. WCS has a similar pH to Grand View, and the clay was of varied mineralogy.

For general cover material and waste, K_d distributions were taken from the WCS PA Model for sand material. WCS has a similar pH to Grand View.

4.2.1.2 Solubility

Aqueous solubilities were also taken from the WCS PA Model with similar materials and geochemical conditions. Some elements (hydrogen, krypton, and radon) were assigned no solubility limit because they exist primarily in the gas phase. Elements without solubility limits have solubility defined as "-1," a special designation that signals GoldSim to allow for infinite solubility. Some elements have element-specific distributions: americium, carbon, iodine, neptunium, plutonium, radium, technetium, and uranium. All other elements were assigned the generic solubility distribution, with a separate distribution for each element and a separate distribution pick for each realization.

4.2.1.3 Water Diffusion

For many elements, sufficient data were not found to support an element-specific distribution for water diffusivity. Instead, a generic distribution was developed that is applied to most elements. The distribution parameters for the generic distribution come from the WCS PA Model with the modification that one distribution applies to multiple elements. In the WCS PA Model, individual distributions for most elements were created. However, in the interest of simplifying the Grand View PA Model for a parameter that may or may not be important, one distribution is assumed to apply to multiple elements.

Hydrogen has its own stochastic definition. It is a smaller molecule when on its own and a larger molecule on occasion when it is combined with other elements, so its distribution is much different. Other element-specific distributions were developed for carbon, iodine, radium, technetium, and uranium. These distributions were taken from the WCS PA Model.

4.2.2 Air

Henry's Law constants, K_H, partitioning between air and water, were based on input distributions for the LANL Area G PA. Soil temperature is used to modify standardized K_Hs at 25°C. A soil temperature distribution was chosen from the Area G PA Model inputs since this should be close to that of the Grand View Site. The Grand View Site is in a mesic soil temperature regime (https://www.nrcs.usda.gov/Internet/FSE_MEDIA/nrcs142p2_050333.jpg) where the mean annual soil temperatures range from 8°C to 15°C for this soil temperature category. It is not clear where the Grand View average soil temperature falls in this range. However, the middle of that range is nearly the same mean as that of the Area G PA Model temperature distribution, which has a wider standard deviation than indicated just by data to account for uncertainty in assumptions of stationarity over time, homogeneity over space, and physical variability due to using one distribution for different depths. The Area G PA Model temperature distribution is appropriate for a preliminary temperature distribution for Grand View, with the range of the distribution from the 1st to 99th percentiles being wider than the mesic soil temperature regime range.

4.2.2.1 Air Diffusion

Air diffusivity coefficients were taken from the WCS PA Model. Free air diffusion coefficients are deterministic values and were given for all gases in the Grand View PA Model: hydrogen, carbon, krypton, iodine, and radon.

The radon emanation factor, or radon escape/production (E/P) ratio, for radon in all materials represents the fraction of radon that escapes the waste or soil matrix and becomes available for transport. This distribution was taken from the WCS PA Model for the radon E/P ratio in waste and was assumed to apply to the entire disposal cell, including both waste and cover.

5.0 Inventory

Three different waste options are built into the Grand View PA Model: current inventory, an inventory based on the safety basis (SB) analysis, a unit inventory and a user-defined inventory for candidate waste. For all three options, radionuclide inventories disposed for that option are applied to the entire volume of the disposal cell. This is unrealistic and overstates the radiologic inventory for the SB inventory because all disposal cells have non-radioactive waste mixed in with the radioactive waste, and this practice is anticipated to continue. The inventory for each option is modeled as deterministic, although the current inventory and user-defined inventory could be modeled with uncertainty.

5.1 Decay Chains

Decay chains are built into the Model using GoldSim's internal species list selection of radioactive species.

5.2 Species List

The Species List in the Grand View PA Model was derived from the actual inventory at USEI, the SB inventory, and progeny from the current inventory and SB inventory. This list of all possible species to include in the Model was screened to remove any radionuclide whose half-life was less than 5 years or more than 1.5×10^{10} years. The lower cutoff for half-life was chosen because 5 years is a standard half-life cutoff for Department of Energy site analyses. The upper bound is chosen because radionuclides with very long half-lives are so long lived as to be essentially stable. The value of 1.5×10^{10} years was chosen so that ^{232}Th is retained in the species list, since it has potentially significant progeny. Even though they have a shorter half-life than 5 years, ^{222}Rn and ^{228}Th were retained in the Species List because of their importance in assessing human health risk.

Inventory from historical disposal and the SB inventory are entered into the Grand View PA Model. Since the Model has a screened Species List as compared to the disposed inventory and SB inventory, special attention is paid to the disposed inventory and SB inventory to account for any short-lived parents of longer-lived radionuclides, which are included in the Model. This is accomplished by rolling up the inventory values of the screened-out species into inventory of progeny radionuclides included in the Grand View PA Model. For example, Ac228 inventory is rolled up into Th228.

5.3 Historical Disposal Data

Radioactive waste inventory disposed of from 2000 through 2015 was provided to Neptune by USEI in an MS Excel file, "*RAd inventory for Neptune modelilng.xlsx*" [sic]. Two different time periods are delineated, 2000-2009 and 2009-2015, corresponding to the time periods when radioactive waste was buried no closer to the surface than 3.6 m versus no closer than 6 m. Estimates were made by US Ecology for what fraction of the inventory in each disposal period was assigned to Cells 14, 15 and 16. The first time period has disposals in Cells 14 and 15. The second time period has disposals in Cells 15 and 16.

The inventory data were entered into the waste cells of the model, divided evenly across all waste depths in the facility, for simplification. The inventory was spread throughout the entire available volume of the disposal cell below the appropriate depth, according to the time of disposal.

5.4 SB Inventory

SB inventory values were taken from the RESRAD input file (USEI 2015).

6.0 Processes

Contaminant transport processes for air, water, erosion, plants, and animals are included in the Grand View PA Model. Climate change is not included with any of these processes. With climate change, hotter and drier weather is expected, with more intense thunderstorms. The effects of this behavior are not explored or included.

6.1 Air Transport

Several parameters contribute to air dispersion of material directly above the cover. The thickness of the modeled atmosphere cell is fixed at 2.0 m, which is the mean value of that parameter distribution in other PA models prepared by Neptune.

Wind speed in the vicinity of the Grand View Site is provided in the CSM as mean annual wind speed of about 4 to 5 m/s (9 to 11 mph). The mean for the normal distribution of wind speed was chosen as the midpoint (4.5 m/s), and the standard deviation was chosen to be the same as that of the Clive DU (Depleted Uranium) PA Model.

The atmospheric mixing height is assumed to have the atmosphere cell height as the maximum mixing height, with a standard deviation the same as the standard deviation of the atmosphere cell height in the Clive DU PA Model.

The atmosphere diffusion height is assumed to have the same distribution as that parameter has in the Clive DU PA Model.

6.2 Water Transport

6.2.1 Water Flux

Since there is no evidence of groundwater recharge (Neptune 2016), the Model does not include an advective flux or advective pathway to groundwater. There is also no diffusive liquid flux below the clay liner beneath the waste because the upper vadose zone is extremely dry and because it is a long distance to the water table. A screening of gaseous diffusion to the groundwater was performed during development of the CSM, which showed low consequence for dose and risk. With the dry environment at Grand View, gaseous diffusion should be an upper bound on water diffusion. Since downward gaseous diffusion does not need to be modeled, neither does downward water diffusion.

With these assumptions, the lower boundary of the Grand View PA Model is the clay liner below the waste.

6.2.2 Saturation

Stochastic input distributions of saturation of porous media with respect to water for cover, waste, and the clay liner layers were chosen based on an informal expert elicitation with Vaughn Thurgood from USEI, as mentioned above in Section 4.1. An informal expert elicitation does not have the same confidence as data collection or a formal expert elicitation. There is some data for the ET cover materials for wilting point and field capacity water contents and saturations. Average saturation for the ET cover material over time and space is assumed to be slightly greater than wilting point, with a standard deviation that allows the distribution to encompass a range of 0.25 to 0.45 and a mean at 0.35. The same distribution was chosen for the RCRA cover, considering that the RCRA cover, composed of more sand and loam, might have a slightly lower water content but also has lower porosity, resulting in similar saturation.

Based on the same conversation, the waste is assumed to be 60% saturated with a range of 50 to 70% (i.e., mean saturation of 0.6 with a range between 0.5 and 0.7). Assuming that translates to three standard deviations of the mean, the standard deviation is at 0.033. Likewise, the clay liner is assumed to be nearly saturated, with a range from 0.9 to 0.95 and a mean at 0.925.

6.2.3 RCRA Cover

The saturation for the RCRA cover is assumed to be the same as that of the ET cover. The RCRA cover might be slightly drier. With the same saturation distribution, water content in the RCRA cover will be slightly less since it has a lower porosity. Saturation is water content divided by porosity.

6.3 Erosion Transport

Basic sheet and wind erosion processes are included in the Model.

6.3.1 Sheet and Rill Erosion

The CSM describes predicted sheet and rill erosion for Cell 16 and for Cells 14 and 15 with the ET cover and established vegetation. Because the model timeframe is long (1,000 yr or more), the established vegetation scenario is more appropriate for the Grand View PA Model than shorter-term cover analyses. As presented in the CSM for Cell 16 with established vegetation, sheet erosion is predicted to be 0.04 short ton/ac·yr (0.09 Mg/ha·yr) for the top slope of the cover and 0.79 ton/ac·yr (1.8 Mg/ha·yr) for the side slopes. For Cells 14 and 15 with established vegetation, sheet erosion for the top slope is predicted to be 0.07 ton/ac·yr (0.16 Mg/ha·yr) for the cover and 0.51 ton/ac·yr (1.1 Mg/ha·yr) for the side slopes. Estimates of the ratio of the top slope area to the total area were made based on engineering diagrams and were used to estimate a weighted average of the erosion rate over all three disposal cells and both top slope and side slope. This average, 1.0 Mg/ha·yr, is used as the mean of the distribution. The standard deviation is set such that three standard deviations is the average side slope erosion rate of 1.8 Mg/ha·yr, which results in a standard deviation of 0.27 Mg/ha·yr.

Sheet and rill erosion were predicted for the RCRA cover for all disposal cells as 0.055 ton/ac·yr (0.12 Mg/ha·yr) for the top slope and 0.59 ton/ac·yr (1.32 Mg/ha·yr) for the side slope, as described in the CSM. Estimates of the total top slope area of all disposal cells and the total area of all disposal cells were used to calculate a weighted average of 0.9 Mg/ha·yr. The standard deviation was calculated such that three standard deviations above the mean is the average side slope erosion rate, resulting in a standard deviation of 0.14 Mg/ha·yr.

6.3.2 Wind Erosion

Wind erosion rates are presented in the CSM for Cells 14, 15, and 16 with the ET cover. A rate of 0.3 ton/ac·yr (0.67 Mg/ha·yr) is most representative of the Site, corresponding to the scenario with established vegetation and soil crust. No estimated wind erosion rates are given for the RCRA cover, so the same values are chosen for wind erosion as are used for the ET cover. The RCRA cover will be composed of more sandy material, making this assumption slightly high for the RCRA erosion rate.

For the standard deviation, we considered the next closest scenario, which has an erosion rate of 3.1 Mg/ha·yr. For a preliminary distribution, the midpoint between these two erosion rates (1.89) was used as the upper bound of what might be expected for the 3rd standard deviation from the mean, resulting in a standard deviation of 0.06.

6.3.3 Erosion Implementation

Erosion is implemented in the Model simply by subtracting the depth that erodes at each time step from the total cover depth. The top soil depths remain the same throughout the Model and the remaining cover depth is distributed into the number of cells in each layer. This implementation slightly concentrates contaminants at each time step throughout the column.

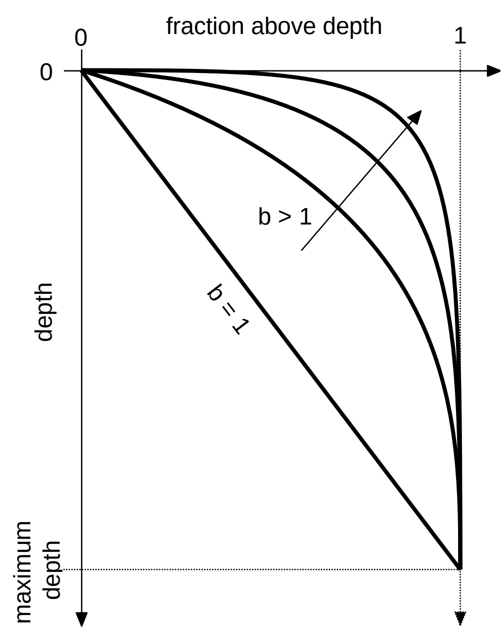
6.4 Biotic Transport

Plant and animal transport parameterization was based on work previously done at the Clive Site in Clive, UT. Clive is the closest ecoregion analog to the Grand View Site. The Clive DU PA Model used data collected on five plots of different vegetation composition in areas near the Clive Site: Mixed Grassland, Black Greasewood, Halogeton—Disturbed, Shadscale-Gray Molly, and Juniper-Sagebrush. The plot with juniper trees was not included in the Grand View PA Model. The Grand View Site does not have trees on it; the closest trees are near the creeks and drainages, which are not onsite. Biotic data were collected for a site-specific study at Clive, so data such as fractions of grasses, forbs, and shrubs, and counts of ant and rodent mounds, may be different at Grand View than at Clive.

In the Grand View PA Model, the functional form used to represent root and burrow densities defines the fraction of all roots above any given depth. At depth $z = 0$, the value is 0 by definition, and at the maximum root depth, where $z = z_i^{max}$, the value is 1, meaning that all roots/burrows are above that depth (the definition of maximum root/burrow depth). The fraction of roots/burrows for plant or animal *i* above any depth *z* is

$$f_i^z = 1 - \left(1 - \frac{z}{z_i^{max}}\right)^{b_i} \quad (1)$$

where



f_i^z	is the fraction of roots/burrows for plant or animal *i* above any depth *z*,
z_i^{max}	is the maximum rooting/burrow depth for plant or animal *i*, and
b_i	is the fitting parameter for the root/burrow density equation for plant or animal *i*.

A value of $b = 1$ indicates a uniform cylindrical "can-shape" distribution of roots/burrows from the surface to maximum depth. Increasing *b* values result in a narrowing of overall width with depth, with $b = 3$ resulting in a "cone-shaped" distribution of roots/burrows, and *b* values greater than 4 indicating increasingly "funnel-shaped" distributions with depth, as might be found in plants producing taproots.

6.4.1 Plants

Total plant biomass for the Grand View Site was derived from online above-ground biomass data from the USGS LandCarbon project, which aims to quantify current and future carbon stocks, greenhouse gas emissions, and related ecosystem metrics. While the LandCarbon results include considerable uncertainty, they are a useful starting point for biomass distribution development. A reasonably large (5-km) buffer was chosen around the Site, such that the estimated biomass distribution spans several vegetation types and some degree of local heterogeneity. Two spatially gridded products from the LandCarbon database were used. "*Biomass Carbon Stocks*" provides an estimate of carbon stored in above- and below-ground biomass on a 2-km grid across the United States. The second product, "*Conterminous United States Land-Use/Land-Cover Mosaics*," provides information on the distribution of natural and anthropogenic land cover on a 250-m grid, which was used to restrict biomass data to certain land cover types. Neptune used data from 2005, because this is the most recent year for which the product was directly verified with observational data.

Plant concentration ratios were chosen from NUREG/CR-5512, Table 6.16 (Kennedy and Strenge 1992) and IAEA TRS 472, Tables 17, 18, 19, and 23 (IAEA 2010) for most elements. For ^{3}H and ^{14}C, the model for plant concentration ratios and associated distributions were taken from the WCS PA Model.

All other plant parameter distributions were taken from the Clive DU PA Model, with the juniper vegetation type excluded.

6.4.2 Animals

Animal distributions were taken from the Clive DU PA Model, with the juniper plot excluded. Ant and rodent colony density, mound volumes, and depths are included in the Model.

6.4.3 Effects of Biotic Modeling on Model Discretization

For each of Cells 14, 15, and 16, the RCRA and ET covers are discretized with the same number of cells in each material unit (cover, select waste, and upper waste). Unless the lower waste layers have the same thickness for each disposal cell (implying the depths of each disposal cell are the same), then the model discretization and cell thicknesses in the lower waste will be different for each disposal cell. If the disposal cell thicknesses are all different in the lower wastes, then it is important to monitor the balance of erosion and biotic intrusion into the cover. If maximum root or burrow depth distributions are revised and penetrate the lower waste layers, the current structure for biotic transport will need to be changed so that biotic transport is calculated for each disposal cell separately.

7.0 Dose Assessment

A summary of parameter values used in the Dose Assessment container of the Grand View PA Model is provided in Table 4. These parameters are used in the dose assessment equations for the exposure scenarios and pathways described in the CSM, including:

- recreational and ranching scenarios,
- construction and well-drilling scenarios, and
- a residential scenario.

For many exposure scenarios, EPA's Exposure Factors Handbook (EFH) (EPA 2011) is used as a reference for parameter deterministic values and distributions. The EFH is a recent collection of the most commonly employed exposure factors used in contaminated site assessments. It is based on reviews of the literature published at the time. Justification for choosing particular studies is provided, and in most cases information is provided that allows derivation of statistical distributions. Additionally, the EFH was peer-reviewed, and the information therein has been employed by risk assessors at numerous sites regulated by EPA and State environmental agencies. Other references, and sometimes professional judgment, are employed to define parameter values for model inputs for which information is unavailable in the EFH. These dose distributions were not reviewed by a statistician, nor were they the result of expert elicitation.

Two distributions were developed with collaboration between subject matter experts and statisticians because of their sensitivity and need for further information, as shown in preliminary models: alpha residence and ranch area size. These distributions and their development are described below.

7.1 Alpha Residence

Alpha residence is an indoor gas attenuation factor (dimensionless); it represents the fraction of a radioactive gas such as radon that infiltrates from soil into a home. The parameter of interest is the fraction of a gas, present in soil pore spaces, that is able to infiltrate through cracks in a slab or basement walls into the interior of the house.

Gas (or vapor, in the case of volatile organic chemicals or VOCs) intrusion occurs when there is migration from any subsurface source into an overlying building. Gas intrusion is a highly complex and variable phenomenon, although in the case of naturally occurring radioactive gases such as radon present in soil, it tends to be less complex than VOCs. The degree of attenuation and thus the value of *Alpha_Residence* depends on a variety of factors related to soil characteristics, building characteristics (e.g., size, exchange rate, etc.), slab characteristics (e.g., thickness, number and size of cracks, etc.), and so on. The majority of studies examining gas intrusion involve VOCs, which are often present in groundwater. However, a number of studies have been performed on radon, largely in the spirit of reducing uncertainty associated with VOC measurement and intrusion (i.e., using radon as a reliable “tracer” surrogate for VOC intrusion).

Alpha_Residence is specifically defined as the ratio of the indoor air gas concentration to the subsurface concentration, ideally measured under the building’s slab. For a radioactive gas, the decay rate is also addressed if measurements over time are made. The scenario of interest here relates to a resident in a single-family home located on top of Cell 16. Radon will be released from wastes, and will migrate through the soil. The sources of variability of interest relate to both intra-house factors (e.g., variation over the year) and inter-house factors, as the specific characteristics of any particular house are uncertain.

The following studies are reviewed to develop a distribution for *Alpha_Residence*. Note that even though this factor is radon-specific, there is a high correlation between the radon *Alpha_Residence* and other-gas *Alpha_Residences* (including VOCs); thus, this distribution can reasonably be applied to any gas at the Site.

The considered studies include:

- EPA 2012: Fluctuation of Indoor Radon and VOC Concentrations Due to Seasonal Variations (EPA 2012)
- King et al. 2010: Use of Radon to Determine Attenuation between Subslab and Indoor Air for Vapor Intrusion Evaluation at Military Housing Units at Fort Wainwright, Alaska (King et al. 2010)
- McHugh et al. 2008: Use of Radon Measurements for Evaluation of Volatile Organic Compound (VOC) Vapor Intrusion (McHugh et al. 2008)
- DiGiulio et al. 2006: Assessment of Vapor Intrusion in Homes Near the Raymark Superfund Site Using Basement and Sub-Slab Air Samples (DiGiulio et al. 2006)

A distribution was developed to capture spatial and temporal variability in *Alpha_Residence*. A wider distribution capturing these sources of physical variability is developed in lieu of defining an average house that the resident will inhabit, given large uncertainty in characteristics of such an average house.

The EPA (2012) reference is not used directly to inform this distribution, as the data are not available in it. Altogether, the remaining sources provide 42 *Alpha_Residence* values. The King et al. (2010) study provides 29 of these values from homes in Alaska. From the King et al. (2010) data, there are three measurements (March 2009, August 2009, Jan 2010) taken from five units (leading to 15 alpha values), plus 14 additional Jan 2010 measurements from 14 additional units. All of the King et al. (2010) data are from paired duplex units, but the pairing is ignored in the distribution development. McHugh et al. (2008) provides two values from two Utah houses (March 2006) and two values from one Oklahoma office building (July and Dec 2006). DiGiulio et al. (2006) provides nine alpha values from nine homes in Connecticut (March 2003).

Data exploration confirmed no strong seasonal pattern or location trend among the sources. Therefore, those sources of variability are not explicitly accounted for in the distribution development. Data were combined across references using a mixed effects modeling approach. The King et al. (2010) study provides three estimates over a time period of about one year on a few selected housing units. These data were not treated as typical time-series measurements, but the dependence among measurements on the same housing unit was taken into account in the model. Total variability is estimated after considering several sources of variability, including variability among different housing units and different references.

For comparison, EPA (2012) developed default *Alpha_Residence* values for VOCs with a median of 0.003, and a 95th percentile of 0.03 for “all residences.” The 95th percentile of the distribution is 0.0046. As the EPA work evaluated VOCs, there may be additional sources of variability in that work that do not relate to radon, and thus these data have limited application to the present work.

A beta distribution is thus defined for *Alpha_Residence* (dimensionless), with the following statistics:

- Mean: 0.0023
- SD: 0.0012
- Minimum: 0

- Maximum: 1

7.2 Ranch Area

Ranch area is the size of a typical ranch in the Grand View area. It is used in the Grand View PA Model to calculate dose to a ranch worker. The time a ranch worker spends onsite is related to the area of the Site divided by the total ranch area.

Ranch data for the Grand View area were chosen from a recent census of agriculture for the state of Idaho (USDA 2012). From that data, a ranch for modeling purposes is defined as a farm with permanent pasture and rangeland that is not cropland or woodland (PRNCW), one of the categories in that census. The census refers to all of the agricultural land as “farms” with various uses and characteristics rather than identifying ranches in particular. A ranch is assumed to be big enough that the cows provide food for the rancher. Other data sources were considered but not included based on representativeness for the Site.

In the state-level data, the number of farms with permanent PRNCW and the total permanent PRNCW (in acres) are documented for each farm group. A distribution is generated using these data. Data are available at the state and county level for farms in Idaho using 12 non-equally spaced size categories (farm groupings): 1–9 acres, 10–49 acres, 50–69 acres, 70–99 acres, 100–139 acres, 140–179 acres, 180–219 acres, 220–259 acres, 260–499 acres, 500–999 acres, 1000–1999 acres, and greater than 2000 acres (USDA 2012).

The three disposal cells represented in the Grand View PA Model—Cells 14, 15, and 16—total 143 acres in size. Because of the model structure the ranch size must be a minimum of this area. Farms with permanent PRNCW less than 143 acres are included in the distribution development, but the distribution is truncated at this minimum value.

To develop the distribution the average PRNCW area for each farm group above is replicated as many times as there are farms in the group. A lognormal distribution was fit using method of moments estimation. The distribution was truncated to be no less than 143.

A lognormal distribution is thus defined for *Ranch area* (acres), with the following statistics:

- Geometric Mean: 111.9
- GSD: 4.5
- Minimum: 143
- Maximum: an arbitrarily large number (1×10^{30})

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